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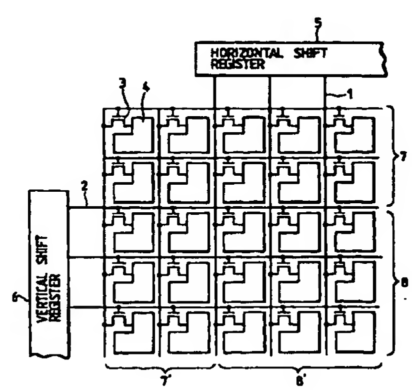
(54) **Liquid crystal display device**

(57) A liquid crystal display device comprises, at least, in a part of a close periphery of the display area of a pixel electrode substrate, a step substantially same as that of the display area.

FIG. 4



EP 1 022 604 A2

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a liquid crystal display device for displaying image or the like.

Related Background Art

[0002] The characteristics required for the liquid crystal display device have become stricter in the recent years, and the displayed image quality on such device is required to be of the same level as in the ordinary CRT image. In the liquid crystal display device, the control of the orientation of the employed liquid crystal is a major factor governing the quality of the displayed image, and uniform and optimum orientation in any part of the display unit is an essential requirement. In general, the orientation of the liquid crystal is controlled by an alignment control film provided on the surface of liquid crystal.

[0003] If such alignment control film has a surfacial step, the orientation of the liquid crystal varies at such stepped portion and becomes no longer uniform. However, particularly on the pixel electrode substrate, the alignment control film develops surfacial steps because of the formation of the pixel electrodes, switching elements, wirings etc. on said substrate. Particularly at the end of the display area, the film position becomes extremely low because of the absence of the adjacent pixel electrode, so that the display characteristics become inferior in such end portion of the display area.

[0004] The liquid crystal display device is composed of mutually adhered two substrates bearing electrodes on the internal faces thereof and sandwiching a liquid crystal layer therebetween, and peripheral circuits for driving the liquid crystal device are often provided in the peripheral area of the pixel areas.

[0005] In the mutual adhesion of both substrates, if a seal area 32 is formed on the peripheral circuits 31 as shown in Fig. 1, there is generated a distribution in the gap of the filled liquid crystal part 33, and an unevenness in color is generated if said distribution exceeds $\pm 0.1\ \mu$.

[0006] On the other hand, if the seal area 32 is provided outside the peripheral circuits 31 as shown in Fig. 2, the chip size becomes inevitably larger, and this will pose a serious problem in a liquid crystal display device requiring a very small cell size, such as that for use in a view finder.

[0007] There is also known a method of forming an insulating planarization film 34 as shown in Fig. 3, but such methods requires an additional step of forming said planarization film 34, and the applied voltage has to be increased if the insulating layer becomes thicker on the pixel electrode. Also in case the substrate is composed of amorphous silicon or polysilicon, the peripheral circuits 31 only show relatively small steps and can therefore be easily planarized, but, in case of monocrystalline silicon substrate, the steps become larger so that the planarization layer 34 has to be made thicker, and an even larger applied voltage is required.

SUMMARY OF THE INVENTION

[0008] In consideration of the foregoing, an object of the present invention is to provide a liquid crystal display device showing uniform liquid crystal cell gap, without expansion in the chip size, and excellent in producibility.

[0009] Another object of the present invention is to provide a liquid crystal display device, in which the orientation of liquid crystal is uniformly controlled even to the end portion of the display area, whereby the image of high quality can be displayed without unevenness over the entire image area.

[0010] Still another object of the present invention is to provide a liquid crystal display device, not requiring an elevated driving voltage, excellent in power saving ability and enabling to reduce the size of the device with respect to the image size.

[0011] Still another object of the present invention is to provide a liquid crystal display device, capable of attaining a uniform cell gap and avoiding unevenness in display color, without the additional steps in manufacture.

[0012] Still another object of the present invention is to provide a liquid crystal display device capable of image display of extremely high quality, without color variations over the entire display area, particularly in the peripheral part of the display area, even in case of color display.

[0013] Still another object of the present invention is to provide a liquid crystal display device having a stepped portion, in at least a part of the surrounding vicinity of the display area of the pixel electrode substrate, substantially same as the step in said display area.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

Figs. 1 to 3 are schematic cross-sectional views of conventional liquid crystal display devices for showing drawbacks in the prior art;

Fig. 4 is a schematic view of a liquid crystal display device of an embodiment 1;

Fig. 5 is a schematic cross-sectional view of a liquid crystal display device of an embodiment 2;

Fig. 6 is a schematic plan view of a liquid crystal display device of an embodiment 3;

Fig. 7 is a schematic plan view of a liquid crystal display device of an embodiment 4;

Fig. 8 is a schematic cross-sectional view of the liquid crystal display device shown in Fig. 7, along a line A-A' therein;

Figs. 9A to 9D are schematic cross-sectional views showing steps of preparation of a semiconductor substrate adapted for use in the present invention; and

Figs. 10 and 11 are schematic plan views of liquid crystal display devices of embodiments 5 and 6.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] The present invention is to provide a liquid crystal display device which is free from the foregoing drawbacks and is capable of providing the liquid crystal with uniform orientation even to the end portion of the device, thereby maintaining uniform display characteristics over the entire image area.

[0016] The above-mentioned objective can be attained, according to the present invention, by a liquid crystal display device which has a step, at least in a part of the surrounding vicinity of the display area of the pixel electrode substrate, substantially same as the step in said display area.

[0017] In the present invention, the formation of said step substantially same as the step in the display area provides a liquid crystal display device of high producibility, having a uniform liquid crystal cell gap, without the expansion of chip with respect to the display area.

[0018] Also the configuration of the present invention allows to provide sharp image display to the end portion of the display area, because the step difference between the display area and the surrounding area, and the resulting difference in the orientation characteristics of liquid crystal, are reduced to zero or are decreased significantly.

[0019] The alignment film of the liquid crystal display device is usually aligned by a rubbing process, and the formation of a step in the peripheral area enables uniform aligning process even to the peripheral area of the display area, so that the uniformity in the aligning property can be further secured and the image display of even higher quality can be achieved.

[0020] The above-mentioned step may be basically formed in any manner in the present invention, but, in consideration of absence of complexity in the manufacturing process, it is preferable to form a dummy area to the pixel area. More specifically, in said dummy area, there may be formed dummy pixels of a same configuration, having same wirings, switching elements, pixel electrodes etc. as in the display area. In such case, the pixel electrodes are preferably insulated electrically, in order to avoid unnecessary voltage application. The formation of such same step by the formation of dummy pixels is easy in manufacture, because the manufacturing process of the pixels in the display area can be merely expanded and the additional steps are not required.

[0021] Also in the present invention, said step may be formed by the circuit elements or wiring provided in the peripheral area. In such case, the shape of the stepped portion is preferably same as that of the adjacent pixels, but the uniformity in cell gap, for example, can be attained even if these parts are of different shapes.

[0022] The above-mentioned dummy pixels can attain the above-mentioned objective, even if they are not same as the pixels in the display area in the layer structure and shape.

[0023] In the present invention, said dummy pixels may be formed only in necessary portions around the four sides of the display area, preferably mutually opposed two sides, and more preferably four sides. The width of such step may vary depending upon the case, but, in case of said dummy pixels, sufficient effect can be attained with a width corresponding, for example, to five scanning lines or display lines.

[0024] The electrically insulated state used in this invention is not critical, and may be suitably selected according to the manufacturing process. For example, in case of a switching element composed of a transistor, such insulated state can be attained by not making contact with the scanning line and the display line. Also said insulated state can be realized by locally cutting off the wiring, or by not making connection with the driving circuit at the end portion.

[0025] Also in case of effecting color display on the liquid crystal display device, a color filter of red, green or blue is attached to each pixel on the counter electrode substrate, and such color filters generate a step at the end portion because of the absence of adjacent color filter. The present invention can however maintain improved uniformity of the orientation of the liquid crystal, by forming a dummy filter in a portion corresponding to the dummy area on the pixel electrode substrate, thereby realizing the identical condition in said dummy area as in the display area.

[0026] It is also possible to render the displayed image sharper by forming an opaque layer in a portion corresponding to the dummy area, thereby rendering said dummy area completely black. It is furthermore possible to form the boundary between the dummy area and the display are under an opaque layer to define the display area by the aperture in said opaque layer, thereby facilitating the alignment of the dummy area and preventing the yield loss resulting from the defective alignment.

[0027] The specific configuration of the present invention will be described in detail in the following embodiments, but the present invention is not limited to the display devices of active matrix type shown in said embodiments.

[0028] It is to be noted that the present invention is by no means limited by the following embodiments, but

is subject to suitable variations within the scope and spirit of the present invention, and it is naturally possible to suitably combine the following embodiments and the disclosures of the present specification.

Embodiment 1

[0029] Fig. 4 shows an embodiment 1 of the present invention, wherein shown are display lines 1; scanning lines 2; TFT (thin film transistor) elements 3; pixel electrodes 4; a horizontal shift register 5; a vertical shift register 6; dummy pixel rows 7; dummy pixel columns 7'; and a display area 8 x 8". Each dummy pixel is in an electrically insulated state, by not making the contact between the gate or source of the TFT element 3 and the scanning line 2 or the display line 1. This embodiment employs TFT elements as switching elements, and two display lines and two scanning lines are assigned for dummy pixels. By surrounding the display area with a dummy area as explained above, same orientation of the liquid crystal can be obtained in the end portions of the display area as in the central portion thereof, and image display of high quality can be attained.

Embodiment 2

[0030] Fig. 5 shows an end portion of the device of an embodiment 2, wherein shown are a TFT substrate 21; insulating layers 22, 22'; alignment films 23, 23'; liquid crystal 24; a sealing material 25; a counter electrode 26; a color filter 27; a polarizing plate 28; and a shield plate 29. In the present embodiment, three pixel electrodes 4 at the right-hand end constitute dummy pixels. In said dummy pixels, the TFT element (not shown) connected to each pixel electrode is connected to a scanning line and a display line, either of which is however not connected to the driving circuit, whereby said dummy pixels are maintained in electrically insulated state. Also the color filters corresponding to three pixels at the right-hand end constitute dummy filters.

[0031] Extremely splendid image display can be ensured by adopting a dummy structure same as in the display area not only on the TFT substrate but also on the opposed substrate.

[0032] The configuration of the present invention is particularly effective in case of color display, since even a slight perturbation in orientation appears conspicuously as a variation in color.

Embodiment 3

[0033] Fig. 6 shows an embodiment 3 of the present invention, which is additionally equipped, in the configuration of the embodiment 2, with an opaque layer. As shown in Fig. 6, the opaque area is wider than the dummy area, and the display area 33 is defined by an aperture in said opaque area. The insulation state of the dummy area is same as in the embodiment 2. In this embodiment the display area is surrounded by a completely black area, so that the displayed image appears sharper.

Embodiment 4

[0034] Fig. 7 is a schematic plan view of a liquid crystal display device of the present embodiment, and Fig. 8 is a schematic cross-sectional view along a line A-A' in Fig. 7. In Figs. 7 and 8 there are shown a pixel area 71 including vertical signal lines, horizontal gate lines and a two-dimensional array of transistor switches positioned at the crossing points of said lines, for transferring signals to the corresponding pixel electrodes; a horizontal scanning circuit 72; a vertical scanning circuit 73 having a same atep as that of said horizontal scanning circuit 72; a horizontal dammy circuit 74 having a same step as that of said horizontal scanning circuit 72; a vertical dummy circuit 75 having a same step as that of said horizontal scanning circuit 72; a liquid crystal seal area 76; liquid crystal 77; a semiconductor substrate 78; and a counter substrate 79.

[0035] A semiconductor substrate 78 consists of a Si substrate, prepared by a process shown in Figs. 9A to 9D. Said Si substrate consists of a Si monocrystalline substrate which is inexpensive, and uniform and flat over a large area, with extremely excellent crystallinity. As semiconductor active elements are formed on a monocrystalline Si layer with very little defects, the floating capacity of said semiconductor elements can be reduced. Thus there can be provided a liquid crystal display unit of high performance, in which elements and circuits capable of high-speed operation, with excellent antiradiation characteristics and without latch-up phenomenon, are integrated with the liquid crystal display pixels on a same substrate.

[0036] In the following there will be explained an example of the manufacturing method of the Si substrate according to Figs. 9A to 9D.

[0037] A P-type (100) monocrystalline Si substrate of a thickness of 300 microns was subjected to anodization in HF solution to form a porous Si substrate 101.

[0038] Said anodization was conducted under the following conditions:

voltage applied:	2.6 V
current density:	30 mA • cm^{-2}
anodizing solution:	HF : H_2O : C_2H_5OH = 1 : 1 : 1
duration:	2.4 hours
thickness of porous Si:	300 μm
porosity:	56 %

[0039] On the P-type (100) porous Si substrate 101 thus prepared, a Si epitaxial layer 102 was grown with a thickness of 1.0 micron, by low pressure CVD. The conditions of deposition were as follows:

source gas:	SiH_4
carrier gas:	H_2
temperature:	850°C
pressure:	1×10^{-2} Torr
growth rate:	3.3 nm/sec.

[0040] Subsequently an oxide layer 103 of a thickness of 1000 Å was formed on said epitaxial layer 102 (Fig. 9A). Then, the other Si substrate 107 on which an oxide layer 104 of a thickness of 5000 Å and a nitride layer 105 of a thickness of 1000 Å were formed was superposed and two Si substrates were firmly adhered by heating for 0.5 hours at 800°C in nitrogen atmosphere (Fig. 9B).

[0041] Then said adhered substrates were subjected to selective etching in a mixture of 49% hydrofluoric acid, alcohol and 30% hydroperoxide (10 : 6 : 50) without agitation. After 65 minutes, the porous Si substrate 101 was completely etched off, with the monocrystalline Si functioning as the etch stopping material, so that the non-porous Si layer alone remained. The etch rate of non-porous monocrystalline Si in the above-mentioned etching solution was very low, and the etched thickness was less than 50 Å even after 65 minutes. In fact the selective ratio of each rate to the porous layer was 10^{-5} or less, so that the etched amount (several tens of Angstroms) in the non-porous layer was practically negligible. Thus the porosified Si substrate 101 of a thickness of 200 μ was eliminated, and a monocrystalline Si layer 102 of a thickness of 1.0 μm could be formed on the SiO_2 layer 103. When the source gas was composed of SiH_2Cl, the growth temperature had to be elevated by several tens of degrees, but the elevated etching property specific to the porous substrate was maintained (see Fig. 9C. It is to be noted that Fig. 9C is shown upside down with respect to Fig. 9B).

[0042] Then TFT's were formed on said monocrystalline silicon film 102, then the Si substrate was covered with rubber resistant to hydrofluoric acid except for the areas directly under the liquid crystal pixel areas, and the silicon substrate was locally removed to the insulation layer by means of a mixture of hydrofluoric acid, acetic acid and nitric acid thereby forming translucent areas 110. In this manner there could be obtained a substrate with TFT as shown in Fig. 9D.

[0043] The semiconductor substrate 8 may be composed of quartz glass instead of Si wafer, but the present invention is particularly effective in case of the monocrystalline Si substrate which is difficult to planarize as explained above.

[0044] The present embodiment can provide a uniform liquid crystal cell gap, because patterns 72 - 75 of a same step are provided on the four sides of a pixel area 71 on the semiconductor substrate 78, and liquid crystal sealing areas 76 are provided on said patterns. Also the chip size can be made smaller because said sealing areas 76 are formed on the peripheral scanning circuits 72, 73. Furthermore excellent producibility is ensured because the dummy circuits 74, 75 can be prepared in a same process as for the peripheral scanning circuits 72, 73.

[0045] Naturally the displayed image quality was excellent as in the foregoing embodiments.

Embodiment 5

[0046] Fig. 10 is a plan view of a liquid crystal display device of the present embodiment, wherein shown are a display area 81 including vertical signal lines, horizontal gate lines and a two-dimensional array of transistor switches arranged at the crossing points of said lines, for transferring signals to pixel electrodes; a horizontal scanning circuit 82 for entering image signals to odd signal lines; a horizontal scanning circuit 83 for entering image signals to even signal lines; a vertical scanning circuit 84 for entering gate signals to odd gate lines; a vertical scanning circuit 85 for entering gate signals to even gate lines; and a liquid crystal sealing area 86, said scanning circuits 82 - 85 having a same step height.

[0047] In the present embodiment, patterns 82 - 85 of a sane step height are positioned on the four sides of the display area 81, and are all utilized as peripheral scanning circuits. Also this embodiment, like the embodiment 4, can achieve a uniform liquid crystal cell gap and a reduced chip size, because the liquid crystal sealing area 86 is formed on the peripheral scanning circuits 82 - 85 of a same step height.

[0048] Also in this embodiment the quality of the displayed image was excellent over the entire display area.

Embodiment 6

[0049] Fig. 11 is a plan view of a liquid crystal display device of the present embodiment, wherein shown are a display area 91 including vertical signal lines, horizontal gate lines, and a two-dimensional array of transistor switches arranged at the crossing points of said lines, for transferring signals to pixel electrodes; a horizontal scanning circuit 92; a vertical scanning circuit 93 for entering gate signals to odd gate lines; a vertical scanning circuit 94, having a same step height as that of the vertical scanning circuit 93, for entering gate signals to even gate lines; and a liquid crystal sealing area 95.

[0050] A sufficiently uniform liquid crystal cell gap can be attained, as in the present embodiment, by placing patterns 93, 94 of a same step height at least on two mutually opposed sides of the display area 91 and providing the liquid crystal sealing area 95 thereon. Also there can be attained a further reduced chip size, as will be apparent from Fig. 11.

[0051] In this embodiment, the steps are not formed on all the sides of the display area, but there can be obtained image display of extremely higher quality, in

comparison with the case where such steps are absent.

[0052] As explained in the foregoing, the liquid crystal display device of the present invention can control the orientation of liquid crystal to the end portions of the display area, thereby enabling to display image of high quality without unevenness over the entire display area, by the formation of steps such as dummy circuits in the surrounding area of the display area.

[0053] Also the present invention can achieve power saving because an elevated driving voltage is not required, and can reduce the size of the liquid crystal display device with respect to the display area size.

[0054] Furthermore, the present invention can provide a liquid crystal display device of a uniform cell gap, thereby providing display without unevenness in color, without increase in the chip size and without addition of extra steps in the manufacture.

[0055] Furthermore, the present invention can provide color image display of extremely high quality, without unevenness in color even in the end portion of the display area.

[0056] The liquid crystal sealing area may be provided on an area of a substantially same step height as that of the display area, and may naturally be provided, not only on circuit elements but also on wirings or dummy areas of a same step height.

[0057] Also formation of an opaque area, corresponding to said stepped area, is effective for obtaining sharper image display.

[0058] In addition, the shape of the step, to be formed adjacent to the pixel area, may be made same as, substantially same as or similar to that of said pixel area by a dummy area, a circuit element or a wiring alone or by the combination thereof.

[0059] A liquid crystal display device comprises, at least, in a part of a close periphery of the display area of a pixel electrode substrate, a step substantially same as that of the display area.

Claims

1. A liquid crystal display device comprising:

    an active matrix substrate having a pixel electrode and a switching element;
    a counter substrate being disposed in opposition to said active matrix substrate with a space between said counter substrate and said active matrix substrate, and being provided with a counter electrode and a color filter disposed in opposition to said pixel electrode; and
    a liquid crystal disposed within said space, wherein a display area is formed by arrange said pixel electrode, and a non-display dummy area is arranged outside of said display area, and wherein
    said counter substrate has a dummy electrode of which film thickness is substantially the same as the thickness of the counter electrode in the display area, and a dummy color filter of which film thickness is substantially the same as the thickness of the color filter in said display area.

2. A device according to claim 1, wherein

    said dummy electrode in the dummy area is formed continuously with the counter electrode in the display area.

3. A device according to claim 1 or 2, wherein

    said counter substrate has further an orientation controlling film on the dummy electrode in the dummy area.

4. A device according to claim 1, wherein

    a light shielding section is provided on an area wider than the dummy area.

5. A device according to claim 1, wherein

    said dummy color filter comprises a red-color filter, a green color filter and a blue color filter.

6. A device according to claim 1 or 2, wherein

    a sealing member is provided for sealing the space between the active matrix substrate and the counter substrate, and an electrode is formed continuously with the dummy electrode between the sealing member and the active matrix substrate.

7. A device according to claim 2, wherein

    a sealing member is provided for sealing the space between the alive matrix substrate and the counter substrate, an electrode is formed continuously with the dummy electrode between the sealing member and the active matrix substrate, and, on said electrode continuously formed, an orientation control film is formed continuously with the orientation control film on the dummy electrode.

FIG. 1 PRIOR ART

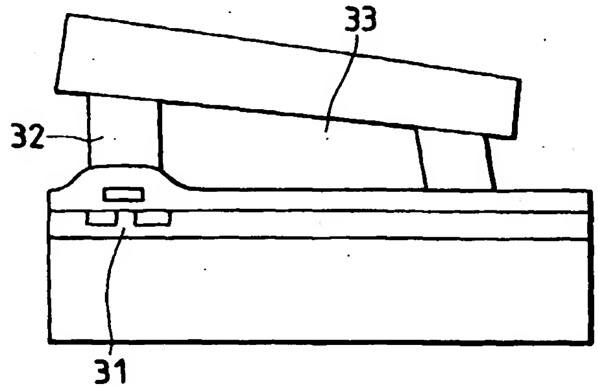


FIG. 2 PRIOR ART

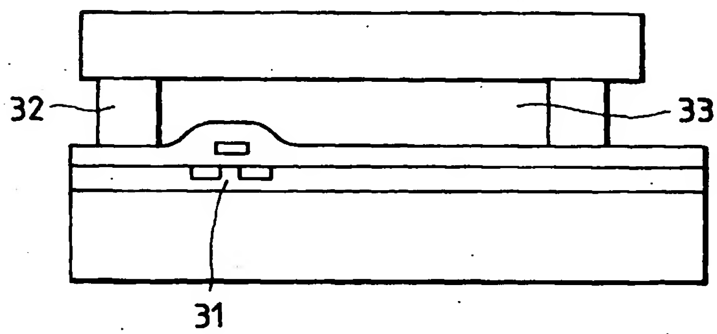


FIG. 3 PRIOR ART

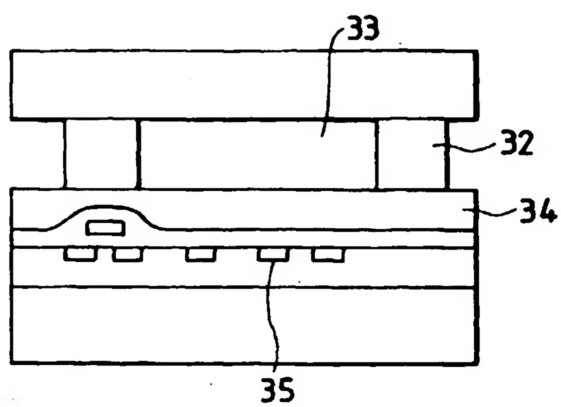


FIG. 4

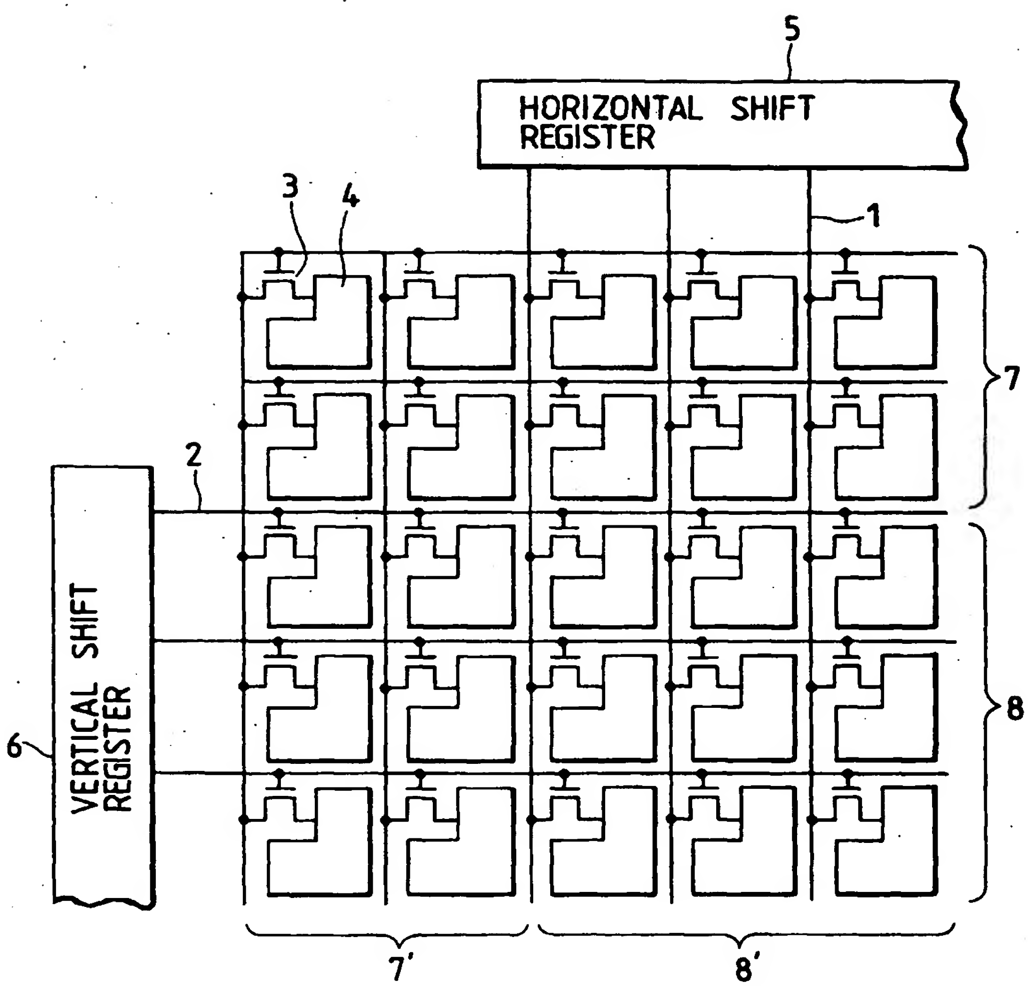

5
HORIZONTAL SHIFT REGISTER
3
4
1
2
7
VERTICAL SHIFT REGISTER
6
8
7'
8'

FIG. 5

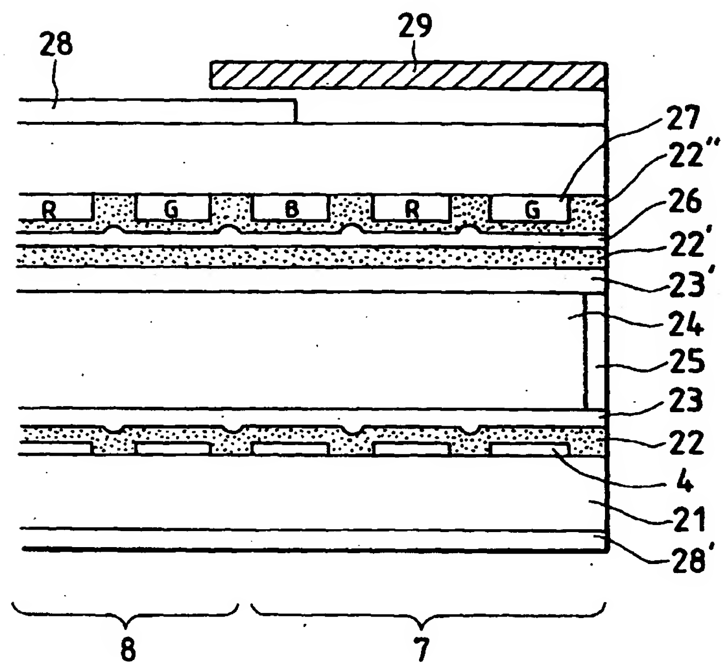


FIG. 6

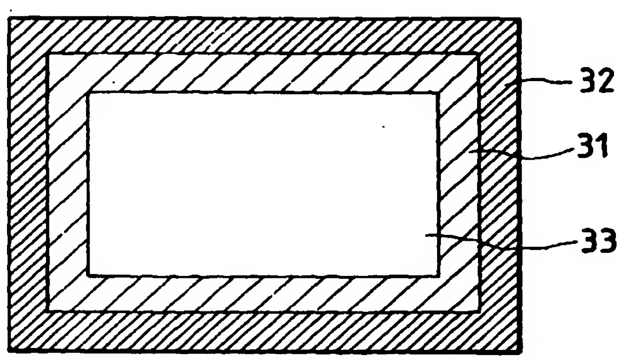


FIG. 7

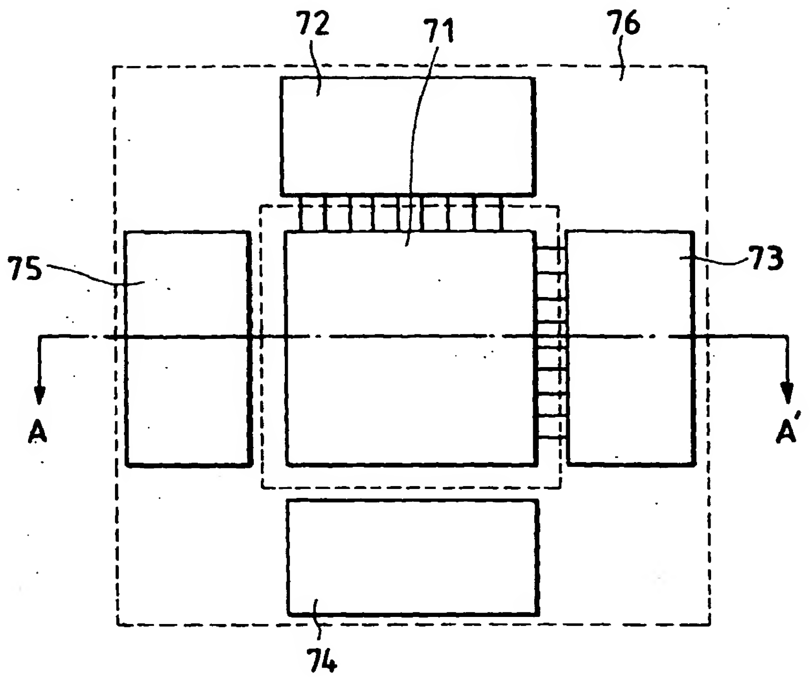


FIG. 8

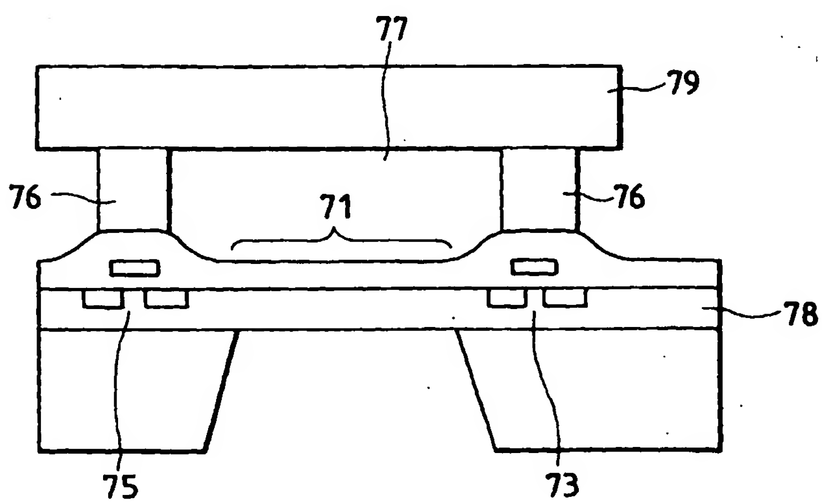


FIG. 9A

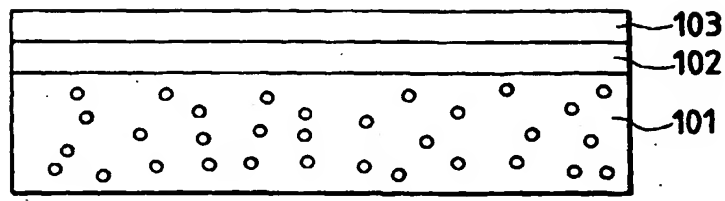


FIG. 9B

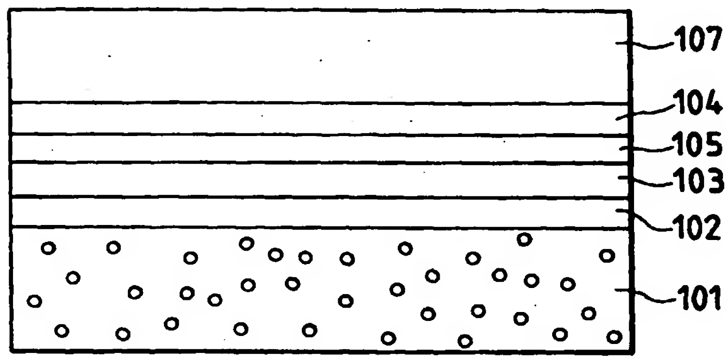


FIG. 9C

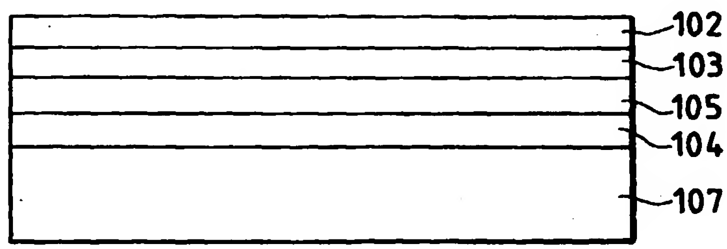


FIG. 9D

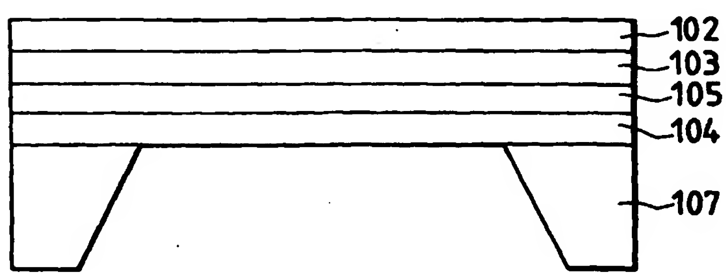


FIG. 10

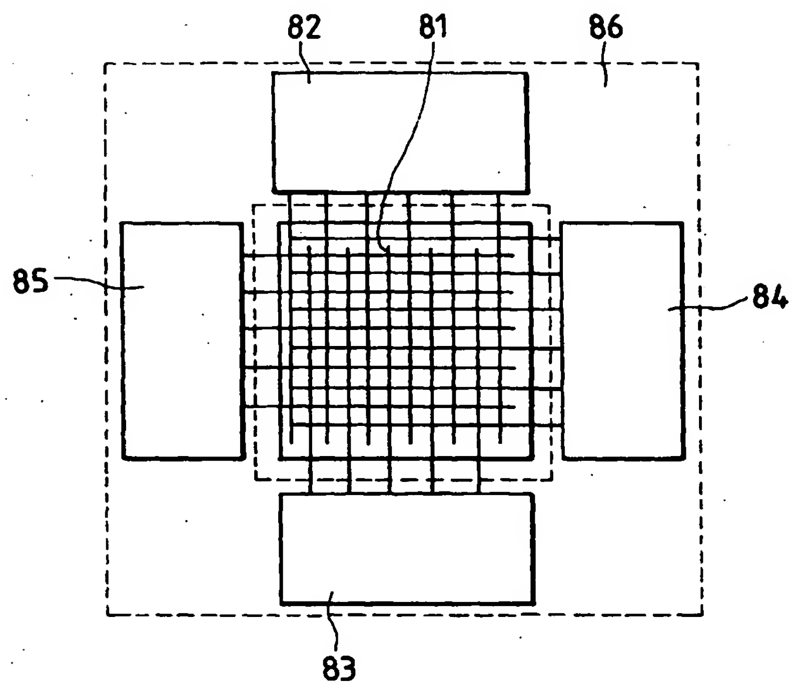


FIG. 11